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Science and Engineering PhDs: A Canadian Portrait

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Science and Engineering PhDs: A Canadian Portrait

Michael McKenzie,
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Summary

People who hold doctorates are an important piston in Canada's labour force engine. They not only represent the highest educational attainment level in a knowledge-based economy, they are also highly skilled industrial researchers and innovators, teachers and professors and scientists who take care of our health as well.

This study profiles the subgroup of scientists and engineers with doctorates at the beginning of the millennium. They are those individuals who held an earned doctorate in agricultural, biological and veterinary sciences, or engineering and applied sciences, or health sciences or mathematics, computer and physical sciences. Using data from the 2001 Census, it analyzes the geographical distribution of this important Canadian workforce, together with the industrial sector where they work and their earnings.

For every woman who held a science or engineering (S&E) doctorate in Canada in 2001, there were four men.

For each age group, earnings of female science and engineering PhDs were significantly lower than those of their male counterparts. For every dollar earned by a male doctorate holder, female doctorates earned 77 cents. In contrast, a female in the general labour force earned 71 cents for every dollar earned by a male.

On average, a scientist or engineer with a PhD employed on a full-time basis earned $70,000, nearly twice the average of $36,000 for Canada's paid full-time workers in 2000.

Science and engineering PhDs in Vancouver had the highest age and gender adjusted earnings.[1] Those in Edmonton had the lowest, just behind Quebec City and Montreal.

Nine out of every 10 scientists and engineers worked in a large city in 2001. The very few rural scientists and engineers tended to be much older than their urban counterparts. Among large cities, the Ontario city of Kingston was the science and engineering PhD capital of Canada, based on labour market concentration rankings.

The majority (60%) of full-time science and engineering PhDs in 2000 were working in the public sector. The largest numbers were employed in educational services.

The private sector paid significantly more than the public sector in 2000 for services offered by young Canadian scientists and engineers with PhDs. However, the gap between public sector and private sector earnings narrowed as the PhDs in science and engineering aged. Earnings in public sector even surpassed, on average, those of the private sector for older workers.

In 2001, employed PhDs were older than the average Canadian worker. The average age of the 100,000 employed PhDs reached 48, and it was 46 for the 57,095 employed science and engineering PhDs. In contrast, the average age for the 15 million employed Canadian workers did not exceed 39.

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1. Literature and current data indicate a clear correlation between earnings, age and gender. For example, earnings are higher with age and female workers earn less. In order to compare cities on an equal basis, an adjustment is done to take out the age and gender effect specific to a city. The adjusted earnings can be interpreted as the average earnings if the two cities would have the same distribution of men and women, younger and older workers.

Because S&E knowledge is one of the keys to a dynamic economy, competitiveness, innovation and productivity growth, examining Canada's stock of S&E PhD human capital remains important. Even with a good stock of human S&E capital, Canada needs to monitor this stock in order to remain prosperous in this increasingly knowledge-based world.

Even if S&E human capital is acquired in many forms including on-the-job learning and formal education, focussing on PhDs remains vital. They are rarer than other S&E human resources and their qualifications are more specific and essential to many kinds of leading-edge scientific and engineering work. Even if they account for most of the total years of S&E education accumulated by Canadians in the past 15 years, technical training diplomas, community college degrees, bachelor degrees and masters degrees are not the focus of this paper even if they are all recognized as very important factors in building S&E human capital.

Male doctorates outnumbered females

Men who held doctorates outnumbered their female counterparts in 2001. This was also true for science and engineering PhDs.

Of a total of just over 100,000 employed doctorate holders in 2001, nearly 73,000 or 73% were men.

In terms of science and engineering doctorates alone, of a total of 57,095 of these individuals, 45,670 were men, representing nearly 80%.

In contrast, women accounted for 47% of employed Canadians, and 57% of university graduates.

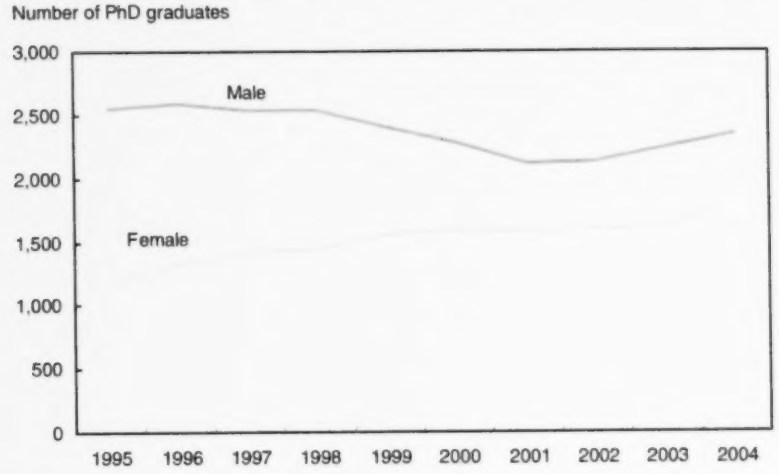
Table 1 Population, labour force and employment by gender and education, Canada, 2001

Sex	Employment				Population
	S&E PhDs	Non S&E PhDs	Total PhDs	Canada	25 and over
Female	11,425	15,695	27,120	6,884,840	10,320,660
Male	45,670	27,250	72,920	7,810,295	9,592,495
Total	**57,095**	**42,945**	**100,040**	**14,695,135**	**19,913,160**

Source: Statistics Canada, special tabulation, 2001 Census of Population.

In 1995 the number of women graduating with a Master's degree had surpassed the number of men. Moreover, the number of women completing undergraduate studies had surpassed the number of men well before then. Men graduating with earned doctorates still outnumbered their woman counterparts in 2004 but the gap narrowed considerably between 1995 and 2001 and then remained stable up to 2004. In 1995, 1,400 more men than women graduated with a PhD; by 2001 this gap had been cut by more than half to 540.

Chart 1 The gap between female and male PhD graduates is narrowing



Source: Statistics Canada, CANSIM table 477-0014.

Women graduating with PhDs in non science and engineering fields, such as education and the social sciences, are in large part responsible for the narrowing of the gender gap in PhD graduates in recent years. Women exceeded men in doctoral enrolments and PhDs awarded in the field of education well before 1995, and in the social sciences since 1997. Presumably, this could reflect a preference by women for social sciences, education and humanities that can partially explain a lower enrolment in S&E.

However, the gap between the number of men and women PhDs in science and engineering may still exist for some time as it is larger and the number of female graduates cannot induce a dramatic change in the labour market in a short time period.

PhDs are older workers

PhDs typically enter the labour force for full-time jobs in their early to mid 30s, so they also tend to be older than the average Canadian worker.

In 2001, the average age of the 100,000 employed PhDs reached 48. In contrast, the average age for the 15 million employed Canadian workers did not exceed 39. In the meantime, the 57,095 employed science and engineering PhDs averaged 46 years old.

In the general population, workers aged 45 and over accounted for only 33% of the employed population aged 25 and over. In contrast, employed PhDs aged 45 and over accounted for nearly 59% of total employed PhDs.

Moreover, PhDs tended to retire later in life. For example, the proportion of PhDs still working after 65 years old is over 5.0% while the equivalent proportion in the general labour force is less than 2.5%.

Table 2 Employment by age group and educational and labour force characteristics, Canada, 2001

Age group	Employment				Population
	S&E PhDs	Non S&E PhDs	PhDs	Canada	25 and over
Under 45	27,675	13,670	41,345	9,490,650	13,035,375
45 to 54	15,795	14,720	30,515	3,455,020	4,393,180
55 to 64	11,105	11,735	22,840	1,444,345	2,847,955
65 and over	2,520	2,820	5,340	305,120	3,624,850
Total	**57,095**	**42,945**	**100,040**	**14,695,135**	**19, 913,160**

Source: Statistics Canada, special tabulation, 2001 Census of Population.

Most employed PhDs work in educational services

In terms of full-year, full-time employment, PhDs worked in educational services more than in any other industrial category in 2000, mostly at universities and colleges. This holds true also when analyzing only science and engineering PhDs.

In fact, more than 60% of the jobs occupied by individuals with science and engineering doctorates were dominated by educational services, health care and social assistance, and public administration, all public sector jobs.

In last place was the manufacturing sector, which accounted for only 5.6% of PhD full-time jobs. In contrast, in the general Canadian labour market, the manufacturing sector employed 16.9% of the population, one of the biggest shares for any sector. Science and engineering PhDs fared better in the manufacturing sector compared to the other PhDs.

Another important difference between S&E and non S&E PhDs can be found in the number of jobs held in the private sector. The proportion of S&E PhDs (41.1%) employed in the private sector was the double of that of non S&E PhDs (21.4%).

In terms of public administration jobs, the federal government alone employed twice as many PhDs on a full-time basis as provincial and local governments.

Table 3 Full-year full-time employment by industry and educational characteristics, Canada, 2000

Industrial classification	Total PhDs		S&E PhDs		Non S&E PhDs		Employed Canadians	
	Count	%	Count	%	Count	%	Count	%
All Industries	**69,285**	**100.0**	**40,710**	**100.0**	**28,570**	**100.0**	**8,685,225**	**100.0**
Total public sector	**46,415**	**67.0**	**23,960**	**58.9**	**22,445**	**78.6**	**1,979,780**	**22.8**
Educational services	32,590	47.0	15,330	37.7	17,260	60.4	555,935	6.4
Public administration	6,220	9.0	4,000	9.8	2,215	7.8	632,870	7.3
Healthcare and social assistance	7,605	11.0	4,630	11.4	2,970	10.4	790,975	9.1
Total private (business) sector	**22,870**	**33.0**	**16,745**	**41.1**	**6,120**	**21.4**	**6,705,445**	**77.2**
Professional, scientific & technical services	10,230	14.8	8,195	20.1	2,035	7.1	597,720	6.9
Manufacturing	3,865	5.6	3,560	8.7	300	1.1	1,467,615	16.9
All other industries combined	8,775	12.7	4,990	12.3	3,785	13.2	4,640,110	53.4

Source: Statistics Canada, special tabulation, 2001 Census of Population.

Female earned less

In 2000, for each age group, earnings of female science and engineering PhDs were significantly lower than those of their male counterparts. These women earned 77 cents for every dollar earned by males who held a doctorate in science and engineering. In comparison, female workers of all educational backgrounds earned 71 cents for each dollar earned by men. Part of the gap may have been due to a difference in number of hours worked, a factor this study did not analyze.

The salary gap between genders for S&E PhDs surpassed $24,000 per year for individuals under 35 years old. It was the age group with the largest gap with male earnings being 53% higher than female earnings.

The private sector paid significantly more than the public sector in 2000 for services offered by young Canadian scientists and engineers with PhDs. Average full-time employment earnings for scientists and engineers under 35 years of age in the private sector were almost $24,000 higher (52%) than those in the public.

However, the gap between public sector and private sector earnings narrowed as the PhDs in science and engineering aged. Earnings in public sector surpassed, on average, those of the private sector for older workers.

PhDs pay follows the trend documented in other papers[2] — the more education a Canadian has, the better the earnings.

2. See René Morissette et al, "Relative Wage Patterns among the Highly Educated in a Knowledge-based Economy", *Analytical Studies Branch Research Paper Series*, 2004, Statistics Canada Catalogue No. 11F0019MIE2004232, http://www.statcan.ca/bsolc/english/bsolc?catno=11F0019M2004232 (accessed September 17, 2007) and Marc Frenette and Simon Coulombe, "Has Higher Education Among Young Women Substantially Reduced the Gender Gap in Employment and Earnings", *Analytical Studies Branch Research Paper Series*, 2007, Statistics Canada Catalogue No. 11F0019MIE2007301, http://www.statcan.ca/english/research/11F0019MIE/11F0019MIE2007301.htm (accessed September 17, 2007).

Table 4 Full-time earnings by age and sex for S&E PhDs and Canadian workers, Canada, 2000

Sex	Age group	Science and engineering PhDs			Canadian workers
		Public sector	Private sector	Both sectors	
		Average earnings in $			
Total	Under 35 years old	46,245	70,328	56,769	34,088
	35 to 44	66,483	75,691	70,919	45,860
	45 to 54	87,168	90,040	88,235	48,677
	55 to 64[1]	94,591	90,586	93,215	47,236
	65 years old and over[1]	94,591	90,586	93,215	40,612
	Total	**78,094**	**81,810**	**79,622**	**43,298**
Female	Under 35 years old	44,797	49,143	46,306	29,574
	35 to 44	58,678	62,556	60,042	37,074
	45 to 54	73,373	71,526	72,885	38,309
	55 to 64[1]	88,213	62,516	82,807	34,545
	65 years old and over[1]	88,213	62,516	82,807	28,172
	Total female	**64,973**	**62,075**	**64,079**	**34,892**
Male	Under 35 years old	63,613	77,652	70,710	37,434
	35 to 44	69,272	78,076	73,818	52,144
	45 to 54	90,562	92,561	91,348	56,314
	55 to 64	95,161	94,223	94,829	54,395
	65 years old and over	97,627	79,016	90,321	44,661
	Total male	**81,582**	**84,863**	**83,005**	**49,224**

1. These groups were combined as the number of observations for the group 65 years old and over were too low for females. To be consistent, the same aggregation was done for the "Total".

Source: Statistics Canada, 2001 Census of Population.

Most science and engineering PhDs in large cities

Canadian scientists and engineers with doctorate degrees appear to cluster around great centres of gravity, in this case large cities. About 9 out of every 10 employed scientists and engineers with PhDs worked in large cities in 2001, the highest concentration when compared to other levels of education.

In comparison, two out of every three employed people (67%) were in large cities for the 15 million employed Canadians.

Rural scientists and engineers tended to be much older than their urban counterparts. Two-thirds (68%) of the 3,850 scientists and engineers employed in rural areas were over 45 years old compared with only half (47%) for the large cities combined.

Recent immigrants with science and engineering PhDs tended to settle in Canada's largest cities such as Toronto, Montreal, and Vancouver. As they were younger than Canadian-born science and engineering PhDs on average, they likely become one of the reasons why close to half of urban scientists and engineers are under 45 years of age.

Table 5 Employment and population counts by educational characteristics and city size, Canada, 2001

	Employed PhDs			Employed Canadians	Canadian population (25 and over)
	Science and engineering	Non science and engineering	Total		
Rural areas	3,850	3,755	**7,605**	2,872,525	4,022,845
Small and medium size cities	3,005	2,585	**5,590**	2,039,610	3,028,815
Large cities	50,240	36,605	**86,845**	9,783,000	12,861,500
Total	57,095	42,945	**100,040**	14,695,135	19, 913,160

Source: Statistics Canada, special tabulation, 2001 Census of Population.

Kingston, Ontario: Science and engineering PhD capital of Canada

In 2001, the Ontario city of Kingston was the science and engineering PhD capital of Canada, based on their concentration in the labour market in the 27 largest Canadian cities.

Ottawa-Hull has been referred to as Silicon Valley North due to the concentration of high technology industries. However, it was second to Kingston both in terms of rankings for the concentration of total PhDs, as well as rankings for the concentration of science and engineering doctorates. Saskatoon was in third place in terms of science and engineering PhDs.

Possible reasons for the good performance of Ottawa-Hull could be found in the higher education sector, notably universities and colleges, in high technology industries as well as the presence of the government sector in Eastern Ontario and Western Quebec.

Looking at the other side of the coin, Saint John, Abbotsford and Oshawa were the three cities least likely to have a big labour force contingent of science and engineering PhDs relative to the size of their labour market.

To give a sense of the difference of concentration of PhDs between two cities, Oshawa and Windsor can be compared as they are both giants in Canada's automotive industry with similar sized labour market populations. There were only 66 science and engineering PhDs for every 100,000 people in Oshawa's labour market in comparison with 282 per 100,000 people for Windsor. In addition, Saskatoon, a city with only a slightly smaller labour market population, had over 700 science and engineering PhDs per 100,000 in 2001.

With the exception of Ottawa-Hull and Toronto, educational services was the leading sector in terms of full-time employment for science and engineering PhDs in the large cities.

In Ottawa-Hull, public administration (mainly the federal government) was the leading employer for these PhDs. In Toronto, the leading industry was professional, scientific and technical services.

Table 6 Scientific and engineering PhD concentration by large city, 2001

Large city	Science and engineering PhDs per 100,000 population 15 and over	Rank (concentration)	Population 15 and over
Kingston (Ont.)	929	1	116,730
Ottawa – Hull (Ont./Que.)	859	2	845,050
Saskatoon (Sask.)	713	3	175,970
Victoria (B.C.)	567	4	259,275
Sherbrooke (Que.)	480	5	122,965
Halifax (N.S.)	450	6	289,855
London (Ont.)	450	7	342,995
Edmonton (Alta.)	449	8	741,160
Québec City (Que.)	443	9	562,750
Vancouver (B.C.)	435	10	1,620,920
Calgary (Alta.)	434	11	756,130
Kitchener (Ont.)	424	12	324,615
St. John's (N.L.)	399	13	140,450
Toronto (Ont.)	391	14	3,728,980
Montréal (Que.)	381	15	2,761,215
Hamilton (Ont.)	332	16	527,545
Winnipeg (Man.)	302	17	533,360
Windsor (Ont.)	282	18	243,200
Greater Sudbury (Ont.)	255	19	125,325
Trois-Rivières (Que.)	182	20	112,455
Regina (Sask.)	171	21	151,700
Thunder Bay (Ont.)	143	22	98,135
St. Catharines – Niagara (Ont.)	128	23	303,635
Chicoutimi – Jonquière (Que.)	130	24	126,680
Saint John (N.B.)	128	25	97,905
Abbotsford (B.C.)	89	26	112,335
Oshawa (Ont.)	66	27	226,840

Source: Statistics Canada, special tabulation, 2001 Census of Population.

Toronto, Calgary and Ottawa-Hull were the three labour markets where the private sector was an important employer of scientist and engineers with PhDs in 2000.

Half of both Calgary and Ottawa-Hull's S&E doctorates who worked full-time were employed by the private sector. In Toronto, 60% of science and engineering PhDs working full-time were employed by the private sector. This contrasts with the other large cities of Canada where it was the public sector that dominated their labour market.

Universities and colleges were the major full-time employers of science and engineering PhDs in the educational services industry. It was the leading industry of full-time employment for 23 of the 25 large cities with available information.

Table 7 Distribution of science and engineering PhDs full-time employment by large city and industry, 2000

Geography	Public sector			Private sector		
	Educational services	Public administration	Health care and social assistance	Professional, scientific and technical services	Manu-facturing	All other industries combined
	% of employment within the city					
Thunder Bay (Ont.)	65.0	10.0	15.0	0.0	0.0	10.0
Kingston (Ont.)	64.8	3.9	6.3	16.4	6.3	2.3
Saskatoon (Sask.)	64.4	13.5	4.3	9.8	3.7	4.3
St. John's (N.L.)	63.4	12.2	4.9	14.6	0.0	4.9
Sherbrooke (Que.)	60.5	9.2	11.8	15.8	2.6	0.0
Kitchener (Ont.)	56.5	1.1	2.3	13.6	14.1	12.4
Trois-Rivières (Que.)	56.0	8.0	16.0	12.0	0.0	8.0
Winnipeg (Man.)	55.9	11.2	10.6	12.2	4.3	5.9
Halifax (N.S.)	54.9	21.0	5.6	9.9	3.1	5.5
Regina (Sask.)	53.6	10.7	14.3	7.1	7.1	7.1
Saint John (N.B.)	53.3	0.0	18.8	0.0	0.0	26.7
Edmonton (Alta.)	50.0	9.2	7.3	21.0	4.0	8.3
London (Ont.)	49.1	7.7	20.7	7.1	8.3	7.1
Québec City (Que.)	48.6	12.9	11.4	19.6	2.9	4.6
Hamilton (Ont.)	44.7	6.9	9.0	13.8	10.1	15.4
Windsor (Ont.)	43.9	0.0	14.6	13.4	20.7	7.3
Vancouver (B.C.)	43.4	2.4	11.6	24.6	3.5	14.4
Greater Sudbury (Ont.)	41.5	14.6	14.6	9.8	4.9	14.6
Montréal (Que.)	39.6	4.1	14.7	20.9	10.8	9.8
St. Catharines – Niagara (Ont.)	38.1	11.9	16.7	11.9	9.5	11.9
Calgary (Alta.)	37.3	3.7	8.6	25.8	4.7	19.4
Victoria (B.C.)	35.0	22.6	6.6	27.7	2.2	5.8
Toronto (Ont.)	21.8	2.8	16.4	23.5	14.5	20.9
Ottawa – Hull (Ont./Que.)	15.3	34.6	3.2	26.2	11.5	9.2

Note: Only large cities with enough number of observations are included.
Components might not add up to 100 due to rounding.
Cities are ranked by the percentage of employment in the educational services sector.

Source: Statistics Canada, special tabulation, 2001 Census of Population.

Highest earnings in Vancouver, lowest in Edmonton

Full-time earnings of scientists and engineers varied depending on the city of work. A comparison of the 10 largest cities shows that Vancouver had the highest adjusted average full-time employment earnings of $89,179 in the year 2000. This was largely due to higher earnings in the public sector.

Age and gender adjustment was performed to eliminate the impact of demographic distortion in the analysis of earnings by cities. Literature and current data indicate a clear correlation between earnings, age and gender. For example, earnings are higher with age and female workers earn less. In order to compare cities on an equal basis, an adjustment is done to take out the age and gender effect specific to a city. The adjusted earnings can be interpreted as the average earnings if the two cities would have the same distribution of men and women, younger and older workers.

Hamilton (Ontario) came in second with earnings of $83,555, again with higher public sector average earnings for PhDs working there.

Of the 10 largest labour markets, private sector earnings were highest in Ottawa-Hull, reaching $88,208 once age and gender were taken into account. Calgary came second with $86,711, and Winnipeg third with $84,793.

The lowest adjusted earnings in 2000 of science and engineering PhDs were found in Edmonton followed by Quebec City and Montreal. S&E PhDs working in the public sector earned the least in Ottawa-Hull and Montreal.

Table 8 Scientific and engineering PhDs full-time earnings in 2000 by sector of employment, the 10 largest cities and Canada

	Average full-time earnings[1] for science and engineering PhDs			Full-time employed science and engineering PhDs	Labour market size
	Private sector	Public sector	Both sectors		
	$			Counts	
Canada	81,834	77,080	79,623	40,710	23,901,360
Toronto (Ont.)	81,450	83,321	82,115	7,815	3,728,980
Montreal (Que.)	76,039	72,381	74,440	5,615	2,761,215
Vancouver (B.C.)	81,854	92,962	89,179	3,740	1,620,920
Ottawa – Hull (Ont./Que.)	88,208	72,168	80,891	4,185	845,050
Calgary (Alta.)	86,711	77,740	82,739	2,030	756,130
Edmonton (Alta.)	72,931	73,002	73,527	2,115	741,160
Quebec City (Que.)	75,436	74,563	74,161	1,400	562,750
Winnipeg (Man.)	84,793	74,191	76,872	935	533,360
Hamilton (Ont.)	80,321	86,785	83,555	950	527,545
London (Ont.)	69,950	75,045	74,715	850	342,995

1. Earnings are age and sex adjusted.

Source: Statistics Canada, special tabulation, 2001 Census of Population.

Data sources, definitions and methods

This study examines the geographic distribution of full-year full-time employment and earnings of Canada's science and engineering doctorates. The identification of the target population is based on the major field of study (MFS) and the highest university degree obtained using the 2001 Census of Population information.

The 2001 Census information refers to the labour force population aged 15 years and over, excluding institutional residents, during the reference week prior to May 15, 2001. The full-time employment and earnings data is for the calendar year 2000. Part-time work activity is excluded. Around 71% of the total Canadian S&E PhD employment was full-time.

Full-time employment refers to full-year full-time work. Full-year refers to a minimum of 49 weeks in the year and full-time is a minimum of 30 hours per week.

Scientists and engineers PhDs were those individuals who held an earned doctorate in one of the four following MFS: (1) agricultural, biological and veterinary sciences, (2) engineering & applied sciences, (3) health sciences, and (4) mathematics, computer and physical sciences.

Scientists and engineers are not limited only to individuals with earned doctorate degrees. There are many Canadian scientists & engineers with medical degrees, masters' degrees, bachelor's degrees, as well as professional certificates above the bachelor's level. The examination of science and engineering workers at the doctorate degree consists of studying only one segment of the Canadian science and engineering employment.

Non science and engineering PhDs were individuals who held earned doctorates in the remaining six MFS (1. social sciences; 2. education; 3. commerce, management and business administration; 4. humanities; 5. fine and applied arts; and 6. no specialization) which comprised the Non-S&E group.

Public and private industrial sectors are based on the 1997 North American Industrial Classification System. Public and private sectors are classified based on majority employment in the aggregation of the 20 major industrial sectors.

Large cities refer to Census Metropolitan Areas (CMAs): urban areas that have attained an urban core population threshold of 100,000 persons. An urban area has a minimum population concentration of 1,000 persons and a population density of at least 400 persons per square kilometre.

Small and medium size cities refer to urban areas that have less than 100,000 urban population.

Rural areas refer to all territories outside an urban area.

A more detailed analysis about the science and engineering PhDs is available. See McKenzie, Michael, "Where are the Scientists & Engineers?," *Science, Innovation and Electronic Information Division Working Papers*, Statistics Canada Catalogue No 88F0006XIE, 2007, http://www.statcan.ca/english/freepub/88F0006XIE/88F0006XIE2007002.htm (accessed September 4, 2007).